Field volatility of Dicamba DGA

Report:	MRID 51017503. Toth, B.N. Off-target Movement Assessment of a Spray Solution Containing MON 76980 + MON 79789 + Intact™ – Southeast Missouri. Unpublished study performed by Stone Environmental, Inc., Montpelier, Vermont; Eurofins EAG Agroscience, LLC, Columbia, Missouri; and AGVISE Laboratories, Northwood, North Dakota; sponsored and submitted by Monsanto Company, Chesterfield, Missouri. Stone Study ID: 19-059-A. Monsanto Study ID: STC-2019-0227. Reference No.: MSL0030828. Experiment initiation September 11, 2019 and completion October 6, 2019 (p. 8). Study and Report completion January 14, 2020.
Document No.:	MRID 51017503
Guideline:	OCSPP 835.8100 and 840.1200
Statements:	The study was completed in compliance with U.S. EPA FIFRA GLP standards (40 CFR Part 160) with the exception of pesticide and crop history, soil taxonomy, test site observations, slope estimates, and study weather data (p. 4). Signed and dated Data Confidentiality, GLP Compliance, Quality Assurance, and Authenticity Certification statements were provided (pp. 2, 4-6, 10).
Classification:	This study is **supplemental**. Dicamba was detected in pre-application samples. Monitoring started after the conclusion of application. The treated area was bare soil, instead of the proposed dicamba-tolerant soybeans. An independent laboratory method validation was not conducted.
PC Code:	128931

Final EPA Reviewer:	Chuck Peck Senior Fate Scientist	Signature: 2020.10.24 Date: 19:24:25 -04'00'
Final EPA Reviewer:	Frank T. Farruggia, Ph.D. Senior Effects Scientist	Signature: 2020.10.25 Date: 12:53:58 -04'00'
CDM/CSS-Dynamac JV Reviewers:	Richard Lester Environmental Scientist	Signature: Date: 3/30/20
	Joan Gaidos Environmental Scientist	Signature: Date: 3/30/20

Executive Summary

Field volatilization of dicamba formulation MON 76980 when tank mixed with glyphosate potassium salt (MON 79789) and Intact™ (polyethylene glycol, choline chloride, and guar gum) was examined from a single bare ground test plot surrounded by non-dicamba tolerant soybean in New Madrid County, Missouri. Vapor sampling and spray drift deposition sampling were conducted for *ca.* 168 hours following application. The products were applied at a nominal rate of 0.5 lbs. a.e./A. The study also examined off-target movement due to volatility and spray drift and resulting impacts to non-target plants. A control plot was established upwind of the test plot for plant effects. No control plot was established for field volatilization measurements.

Air temperatures, surface soil temperatures, and relative humidity the day of application (9/11/19) ranged from 24.6-33.2°C (76.3-91.8°F), 26.5-45.9°C (79.7-114.7°F), and 46-83%, respectively. Air temperatures, surface soil temperatures, and relative humidity ranged from 18.4-36.2°C (65.1-97.1°F), 21.8-53.0°C (55.0-127.3°F), and 29-98%, respectively, 1 to 7 days after application.

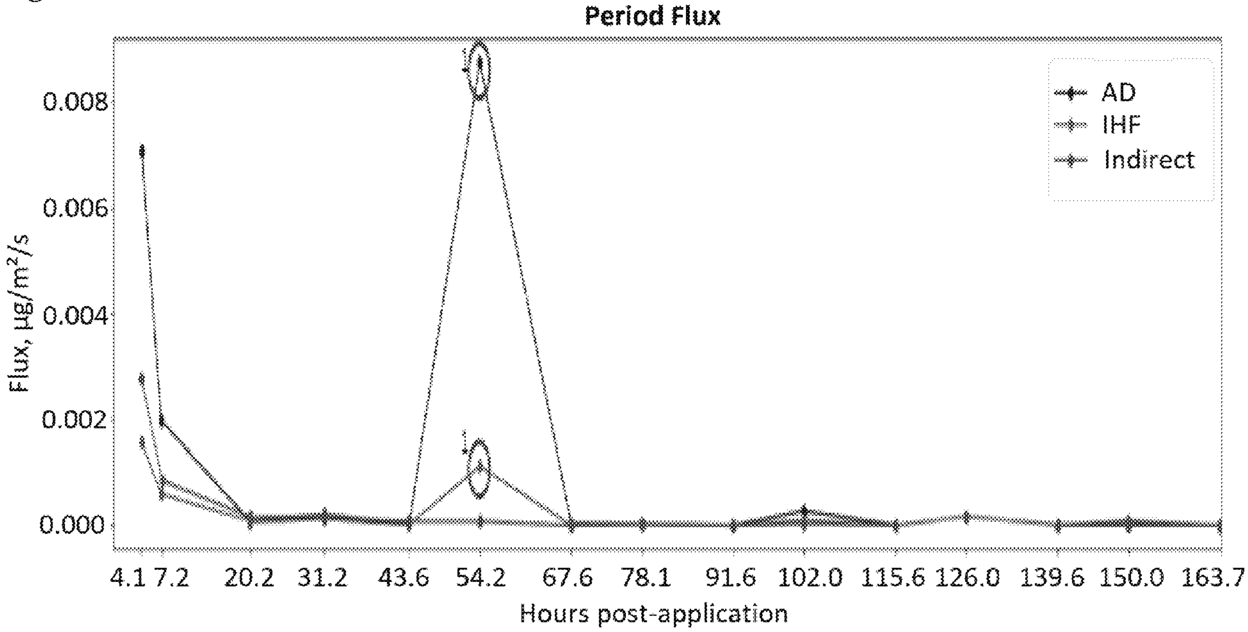
Under field conditions at the test plot, based on calculations using the Indirect method, a peak volatile flux rate of 0.002787 $\mu g/m^2 \cdot s$ was estimated by the reviewer and study authors, accounting for 0.071% of the applied dicamba observed 0.5 to 5.2 hours post-application. By the end of the study, a total of 0.156% of dicamba volatilized and was lost from the field. Peak and secondary peak volatile flux rates occurred during the warm daytime hours in the days after application.

Under field conditions at the test plot, based on calculations using the Integrated Horizontal Flux method, a peak volatile flux rate of 0.001566 $\mu g/m^2 \cdot s$ was measured accounting for 0.040% of the applied dicamba observed 0.5 to 4.4 hours post-application. By the end of the study, a total of 0.16% of dicamba volatilized and was lost from the field. The highest secondary flux rate of 0.001120 $\mu g/m^2 \cdot s$ (Hours 44-54) was considered anomalous by the study authors and was excluded from the calculation of mass lost from the field; however, the reviewer could not identify anything anomalous with the concentration or wind speed profiles that would preclude the use of the flux rate. Peak and secondary peak volatile flux rates occurred during the warm daytime hours in the days after application.

Under field conditions at the test plot, based on calculations using the Aerodynamic method, a peak volatile flux rate of 0.008745 $\mu g/m^2 \cdot s$ was measured 44.0 to 54.4 hours post-application. This flux rate was considered anomalous by the study authors based on a comparison of perimeter and center mast sample concentrations and was excluded from the calculation of mass lost from the field; however, the reviewer could not identify anything anomalous with the concentration, temperature, or wind speed profiles that would preclude the use of the flux rate. The largest secondary peak volatile flux rate of 0.007062 $\mu g/m^2 \cdot s$ occurred 0.5 to 4.4 hours post-application and accounted for 0.179% of the applied dicamba. By the end of the study, a total of 0.84% (0.261% based on study author calculations) of dicamba volatilized and was lost from the field. Peak and secondary peak volatile flux rates occurred during the warm daytime hours in the days after application.

Spray drift measurements indicated that dicamba residues were not detected above the no observed adverse effects concentration (NOAEC, 2.6×10^{-4} lb ae/A, or a deposition fraction of 5.2×10^{-4}) in any of the upwind, left wind, or right wind samples at one hour after application. Dicamba residues were detected at a maximum fraction of the amount applied of 0.012640 in downwind samples. Deposition of dicamba above the NOAEC was detected in all three transects of the downwind direction in the one-hour sampling period. Study authors estimated distances from the edge of the field to reach the NOAEC for soybean ranging from 23.5 to 41.6 m in the downwind direction. The reviewer-estimated distance was 31 m (27.6 to 36.1 m for all three transects) in the downwind direction.

Figure 1 Volatile flux – Bare Ground Plot



[1] Red circles indicate data points considered to be anomalous by study authors.

Plant effects (51017503, EPA Guideline 850.4150; Supporting files in Appendix 2)

The effect of **MON 76980 (a.i. Dicamba diglycolamine (DGA) salt) + MON 79789 (a.i. Glyphosate potassium salt) + Adjuvant Intact™** on the vegetative vigor of dicot (soybean, *Glycine max)* crops was studied in a spray drift and volatilization study. Nominal test concentrations of Dicamba were 0.50 lb ae/A and Glyphosate were 1.125 lb ae/A. It is noted that the application was made to a bare field rather than a standing crop of DT-soybeans. Dicamba test concentrations were analytically confirmed by monitoring field filter collectors during spray application as well as measurement of pre-application and post-application tank solutions; nominal and measured application rates are provided in Table 4. On day 28 the surviving plants along several transects projecting from the treated area were measured for height and visual signs of injury. Notably, this study was conducted late in the summer with plants that were planted in July and final assessment of effects being observed in September. It is unclear how this late season study may relate to potential effects during the (May-July).

The growth medium used in the vegetative vigor test were field soils located in test plots located upwind, downwind and laterally from the treatment field (West samples: sandy loam, pH 6.9, organic matter 1.7%; East samples: sand, pH 6.4, organic matter 0.93%). On day 28 the surviving plants were measured for height.

Spray Drift + Volatility Study

Dicamba-non-tolerant soybean were planted in test plots at distances of approximately 3, 5, 10, 20, 40, 50, 60 and 120 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions. Height effects and visible signs of injury (VSI) were recorded up to 28 days after spray application of the tank mix.

Regression based distances to a 5% reduction in plant height were evaluated for each individual transect. The plant height data from control plots were used to establish the baseline 5% effect level plant height.

Visible symptomology was reported, but the specific phytotoxic symptoms were not. VSI distances were established based on regression estimated distances to a 10% VSI. For the drift study, three of the downwind transects, two of the left wind transects, and the east diagonal transect showed a dose-response relationship between percent of visual symptoms and distance to the treatment field. Percent of visible symptoms was a maximum of 55% in these fields closest to the treatment field.

Furthest distance to 5% Reduction in Plant Height = 62.0 meters (203.4 feet)
Furthest distance to 10% VSI = 87.5 meters (287.1 feet)

Volatility Study

Dicamba-non-tolerant soybean were planted in test plots at distances of approximately 3, 5, 10, and 20 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions and isolated using plastic sheeting (transect covers) during the application period to prevent exposure to spray drift. Height effects and visual symptomology was recorded up to 28 days after spray application of the tank mix.

When compared to the negative control plot, the study author and reviewer found significant inhibitions in plant height and VSI along several transects.

Furthest distance to 5% Reduction in Plant Height = 9.9 (32.5 feet)
Furthest distance to 10% VSI = 20.1 meters (<65.9 feet)

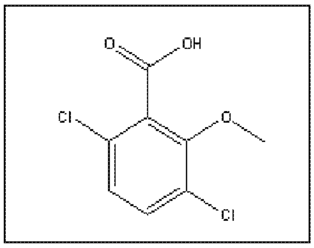
Table 1. Estimated distances to regulatory threshold responses for reductions in plant height and visible signs of injury.

Exposure Pathway	Spray Drift + Volatility (uncovered transects)		Volatility (covered transects)	
Transect	Distance to 5% Height (meters)	Distance to 10% VSI (meters)	Distance to 5% Height (meters)	Distance to 10% VSI (meters)
DWA	17.5[b]	57.0[a]	<3 [d]	13.6[b]
DWA-D	20.9[a]	11.7[a]	NA	NA
DWB	29.0[a]	48.0[a]	<5	20.1[b]
DWC	62.0[b]	87.5[a]	9.9[a]	10.6[a]
DWC-D	20.2[b]	19.7[a]	NA	NA
LWA	<3[d]	<3 [d]	<20 [d]	<3 [d]
LWB	<20 [d]	<10 [d]	<3 [d]	<3 [d]
RWA	<3 [d]	<3 [d]	<3 [d]	<3 [d]
RWB	<3 [d]	26.9[c]	<10 [d]	<5 [d]
UWA	<20 [d]	<3 [d]	<3 [d]	<3 [d]
UWB	<3 [d]	<3 [d]	<3 [d]	<3 [d]
UWB-D	<20 [d]	<3 [d]	NA	NA

[a] distance estimated with logistic regression
[b] distance estimated with polynomial regression
[c] distance estimated with linear regression
[d] distance estimated visually

I. Materials and Methods

A. Materials



1. Test Material

Product Name: MON 76980 (Appendix B, pp. 87-88)
Formulation Type: Liquid
CAS #: 104040-79-1
Lot Number: 11495284
Storage stability: The expiration date of the test substance was March 10, 2020.

Product Name: MON 79789
Formulation type: Liquid
CAS Number: 70901-12-1
Lot Number: 11495283
Storage stability: The expiration date of the test substance was May 10, 2020.

Product Name: Intact (polyethylene glycol, choline chloride, guar gum)
Formulation type: Liquid
Lot Number: 0831B037000 (Batch# 374-25)
Storage stability: The expiration date of the test substance was May 10, 2020.

2. Storage Conditions

The test substances were received on May 10 and May 16, 2019 and stored at MOARK Agricultural Research, LLC, Fisk, Missouri (Appendix B, p. 88). The test substance was sprayed on the test plot on September 11, 2019 (p. 14). The study protocol indicates the test substance would be stored under label conditions in a monitored pesticide storage area adequate to preserve stability (Appendix A, pp. 38-39).

B. Study Design

1. Site Description

The test site was located in New Madrid County, Missouri, *ca.* 5.5 miles east of Matthews, Missouri (Appendix B, p. 89). A single bare ground field, measuring *ca.* 903 ft × 903 ft (274 m × 274 m, 18.7 A) was treated with a mixture of MON 76980 (containing dicamba), MON 79789 (containing glyphosate potassium salt), and Intact^{TM} (polyethylene glycol, choline chloride, and guar gum). The bare ground plot was surrounded by a 110-ft buffer planted in non-dicamba tolerant soybeans (Variety: Beck's 186899; Lot: R193141M). Soil characterization indicated the

USDA textural class was sandy loam to the west of the service road dividing the test plot and sand to the east of the service road (Appendix B, p. 103). Prior to the study, dicamba had most recently been applied to the test plot field during the 2018 growing season (Appendix B, p. 91). Crop history for the three years preceding the study indicated the field had been planted in corn, cotton, and soybean (Appendix B, pp. 151-153). Terrain was flat with a slope between 0 and 1%. The test plot was surrounded primarily by agricultural land (Appendix B, Figure 1, p. 129). The test plot and surrounding buffer zone were planted with soybean on August 1, 2019 (Appendix B, pp. 89-90). The soybean seeds were planted at a density of 140,000 seeds/A on 30-inch row spacing for both plantings. The test plot was disced to bare ground and the crop destroyed on September 10, 2019 due to the soybeans beginning bloom (R1 stage) which would not have allowed for application consistent with product labelling.

2. Application Details

Application rate(s):	The target application rate was 0.5 lb a.e./A or 15 GPA (pp. 14-15; Appendix A, p. 39; Appendix B, p. 91). Four application monitoring samples consisting of four filter paper samples each were positioned in the spray area in locations to capture various portions of the spray boom (Appendix B, p. 96). The spray rate was automatically maintained by a variable rate controller (Appendix B, p. 102). The application rate was assumed to be 100% of the target rate. The actual application rate calculated by Climate FieldView™ software was 103% of the target application rate or 15.4 GPA (Appendix B, Table 3, p. 110).
Irrigation and Water Seal(s):	A scheduled irrigation event occurred overnight on September 16, 2019. No precipitation events occurred during the 168-hour field volatility study (Appendix B, Table 11, pp. 122-123).
Tarp Applications:	Tarps were not used on the test plot. Tarps were used on nine plant effects transects before application, during application, and for at least 30 minutes following application to prevent exposure to spray drift to assess secondary movement only (volatility; Appendix A, p. 44).
Application Equipment:	A John Deere R4030 ground sprayer equipped with a 90-ft boom was used for the spray application (Appendix B, pp. 90-91). 73 Turbo TeeJet® Induction nozzles (TTI 11004) were installed with 15-inch spacing and the boom height was set at 20 inches above the crop canopy (25 cm). The sprayer had one spray tank with a volume of 800 gallons.
Equipment Calibration Procedures:	Nozzle uniformity was tested by spraying water at a pressure of 63 psi through the boom and measuring nozzle output using SpotOn® Model SC-1 sprayer calibrator devices (Appendix B, p. 91). Each

nozzle was tested three times to determine variability. Calibration of the sprayer and nozzles established the total boom output per minute of spray to be 37.2 GPM. The forward speed of the sprayer tractor was calibrated by timing the duration required, in seconds, to drive a known distance of 300 ft. Speed verification was repeated three times.

Application Regime: The application rates and methods used in the study are summarized in **Table 2**.

Table 2. Summary of application methods and rates for dicamba

Field	Application Method	Time of Application (Date and Start Time)	Amount Dicamba Applied[1] (lbs)	Area Treated (acres)	Calculated Application Rate[2] (lb ae/acre)	Reported Application Rate (gal/acre)
Bare ground	Spray	9/11/2019 at 11:27	9.63	18.7	0.515	15.4

Data obtained from Appendix B, p. 92 and Appendix B, Table 3, p. 110 of the study report.
[1] Reviewer calculated as calculated application rate (lb a.e./acre) × area treated (acres).
[2] Reviewer calculated as percent of target applied (103%) × target application rate (0.5 lb a.e./acre, Appendix B, p. 105).

Application Scheduling: Critical events of the study in relation to the application period are provided in **Table 3**.

Table 3. Summary of dicamba application and monitoring schedule

Field	Treated Acres	Application Period	Initial Air/Flux Monitoring Period[1]	Water Sealing Period	Tarp Covering Period
Bare ground	18.7	9/11/2019 between 11:27 – 11:44	9/11/2019 between 11:54 – 16:03	Not Applicable	Not Applicable

Data obtained from Appendix B, p. 92; Appendix B, Table 6, p. 113; and Appendix B, Table 8, p. 117 of the study report.
[1] Initial air monitoring period is that for perimeter stations. The initial period at the center station was 9/11/2019 between 11:58 – 15:51.

3. Soil Properties

Soil properties measured before the study are provided in **Table 4**. pH of the soil was 6.9 in the west sample and 6.4 in the east sample (Appendix B, Tables 1-2, pp. 108-109).

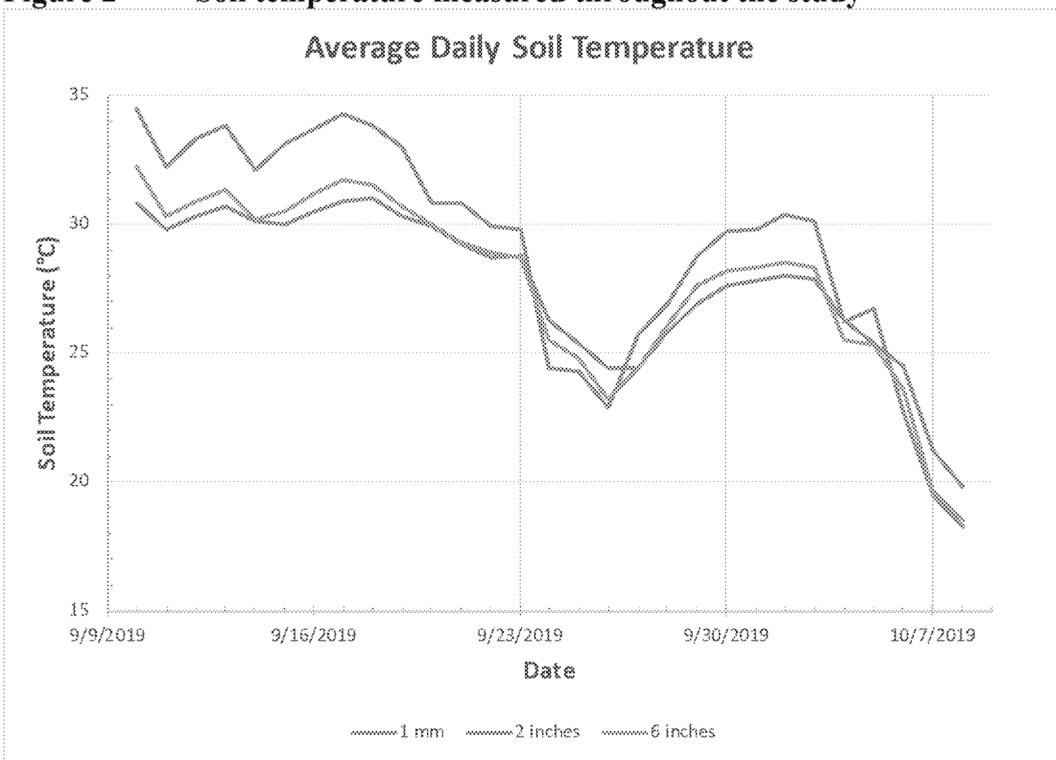
Table 4. Summary of soil properties for the bare ground plot

Field	Sampling Depth (inches)	USDA Soil Textural Classification	USGS Soil Series	WRB Soil Taxonomic Classification	Bulk Density (g/cm^3)	Soil Composition
West Sample	0-6	Sandy Loam	Not Reported	Not Reported	1.24	% Organic Carbon[1] = 0.99% % Sand = 76% % Silt = 12% % Clay = 12%
East Sample	0-6	Sand	Not Reported	Not Reported	1.36	% Organic Carbon[1] = 0.54% % Sand = 90% % Silt = 6% % Clay = 4%

Data obtained from Appendix B, pp. 94, 103, and Appendix B, Tables 1-2, pp. 108-109 of the study report.
[1]Reviewer calculated as: organic carbon (%) = organic matter (%)/1.72. Organic matter was reported as 1.7% in the west sample and 0.93% in the east sample.

Figures 2 and 3 are plots of soil temperature and soil moisture measured throughout the study.

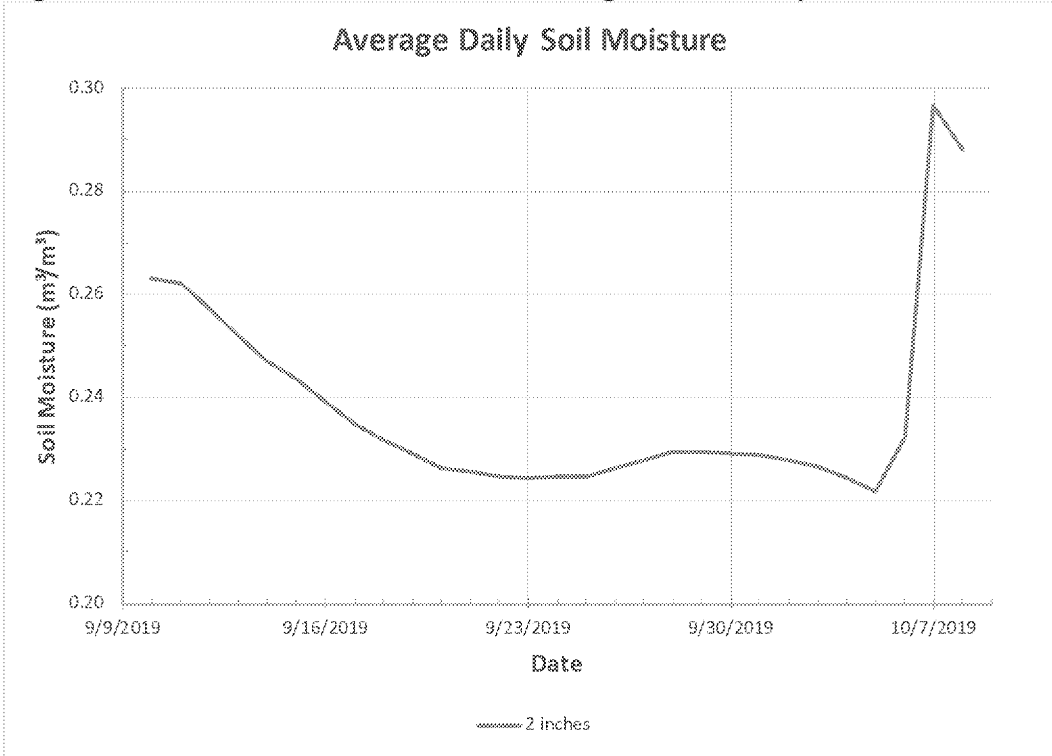
Figure 2 Soil temperature measured throughout the study



Data obtained from Appendix B, Table 10, pp. 120-121 of the study report.

ED_005172C_00001231-00008

Figure 3 Soil moisture measured throughout the study



Data obtained from Appendix B, Table 12, pp. 123-124 of the study report.

4. Source Water

Tank mix water was obtained from a well. The pH of the tank mix water was 7.51 as measured at the field, with pH at the analytical laboratory of 8.5, an alkalinity of 163 mg $CaCO_3$/L, and a conductivity of 0.46 mmhos/cm.

5. Meteorological Sampling

Five meteorological stations were used to collect weather data during the study (Appendix B, p. 92).

The 10-meter main meteorological station was located upwind of the test plot (Appendix B, pp. 92-93, and Figure 1, p. 129). The system included a Campbell CR6 data logger and a Campbell Scientific CELL210 module to remotely monitor data. All parameters were reported at heights of 1.7, 5, and 10 m. The station included sensors for monitoring windspeed and direction (3D anemometer and 2D anemometers), air temperature, and relative humidity.

A boom height anemometer collected wind speed and wind direction data during application at a height of 20 inches above the disced bare ground (Appendix B, p. 93). The anemometer was located *ca.* 5 m downwind of the sprayed area.

The long duration main meteorological station was located upwind of the test plot and recorded data for 28 days post-test substance application (Appendix B, p. 93, and Tables 10 and 11, pp.

120-123). The station included wind speed and direction sensors (1.76 m), a rain gauge sensor (1.58 m), a temperature/relative humidity sensor (1.21 m), a pyranometer to measure solar irradiation (1.54 m), three soil temperature sensors (depths of 1 mm, 2 inches, and 6 inches), and one soil moisture sensor (depth of 2 inches).

The primary flux meteorological station was deployed outside of the plot prior to application and was then moved to the center of the plot, remaining there until after the final drift sample was collected on the morning of September 18, 2019 (Appendix B, p. 93). The station included a Campbell CR6 data logger and a Campbell Scientific CELL210 module to remotely monitor data. The station included sensors for air temperature, relative humidity, wind speed, and wind direction at heights of 0.33, 0.55, 0.9, and 1.5 m above the disced bare ground.

A secondary flux meteorological station was positioned upwind and outside of the sprayed area and recorded air temperature, relative humidity, wind speed, and wind direction at heights of 0.33, 0.55, 0.9, and 1.5 m above the disced bare ground (Appendix B, pp. 93-94).

Details of the sensor heights and the meteorological parameters for which data were collected are illustrated in **Table 5**. The location of the meteorological equipment is shown in **Attachment 3**.

Table 5. Summary of meteorological parameters measured in the field

Field	Minimum Fetch (m)	Parameter	Monitoring heights (m)	Averaging Period
Bare Ground 10-Meter Main Met. Station	Not Reported	Air temperature	1.7, 5, and 10	1 minute
		Relative humidity	1.7, 5, and 10	1 minute
		Wind speed/wind direction	1.7, 5, and 10	1 minute
Bare Ground Boom Height Anemometer	Not Reported	Wind speed/wind direction	0.51	Not Reported
Bare Ground Long Duration Main Met. Station	Not Reported	Precipitation	1.58	1 minute
		Air temperature	1.21	1 minute
		Relative humidity	1.21	1 minute
		Soil temperature	1 mm, 2 inches, 6 inches	1 minute
		Soil moisture	2 inches depth	1 minute
		Solar radiation	1.54	1 minute
		Wind speed/wind direction	1.76	1 minute
Bare Ground Primary Flux Met. Station	146.72	Air temperature	0.33, 0.55, 0.9, and 1.5	1 minute
		Relative humidity	0.33, 0.55, 0.9, and 1.5	1 minute
		Wind speed/wind direction	0.33, 0.55, 0.9, and 1.5	1 minute
Bare Ground Secondary Flux Met. Station	Not Reported	Air temperature	0.33, 0.55, 0.9, and 1.5	1 minute
		Relative humidity	0.33, 0.55, 0.9, and 1.5	1 minute
		Wind speed/wind direction	0.33, 0.55, 0.9, and 1.5	1 minute

Data obtained from Appendix A, pp. 47-48; Appendix B, pp. 92-94; and Appendix D, Table 8, p. 557 of the study report.

6. Air Sampling

Two pre-application samples were collected at 0.15 m above the ground at the approximate center of the test plot (Appendix B, pp. 96-97). Samples were collected for *ca.* 6 hours on September 10, 2019 from 10:13 to 16:30.

Post-application in-field air samplers were used for flux monitoring for *ca.* 168 hours following application (Appendix B, p. 97). Samplers were placed on a mast in the approximate center of the plot directly following spray application at heights of 0.15, 0.33, 0.55, 0.90, and two at 1.5 m above the ground. Samples were collected at *ca.* 6, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. The 0 to 6-hour and 6 to 12-hour samples were pro-rated based on the time remaining until sunset on the day of application, with subsequent samples being collected on a sunrise-sunset schedule.

Off the plot, eight perimeter air monitoring stations were located 1.5 m above the crop canopy and 5 m outside the edge of the plot (Appendix B, p. 97). Samples were collected at *ca.* 6, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. The sampling schedule was the same as for the in-field air sampling.

7. Spray Drift Monitoring

The spray drift test system consisted of three downwind transects, two left wind transects, two right wind transects, and two upwind transects (Appendix B, pp. 98-100). All transects were perpendicular to the edge of the field. Deposition collectors (Whatman #1 15 cm diameter filter papers) were placed on all transects at the following distances from the edge of the spray area: 3, 5, 10, 20, 40, 50, and 60 m. Deposition collectors were also placed at 120 m in the downwind transects only. Deposition collectors were secured to carboard squares and attached to a horizontal plastic platform at crop height. Initial deposition samples were supposed to be collected 5 minutes after spray application was completed; however, actual initial downwind deposition sample collection occurred up to 40 minutes after the start of application. Deposition samples were collected at intervals of 1, 24, 48, 72, 96, 120, 144, and 168 hours post-application. A scheduled irrigation event occurred overnight during the 120-hr sampling period on September 16, 2019. All filter paper samples were reported as damp but did not impact sample collection on the morning following the irrigation event.

8. Plant Effects Monitoring

The off-target movement of dicamba due to spray drift and volatility following the application of dicamba to bare ground was assessed by comparing plant heights and visual plant symptomology along transects of non-tolerant soybean crop surrounding the treated field and perpendicular to the sprayed field edges of the application area, as well as four transects radiating from the corners of the sprayed field out to a maximum distance of approximately 120 meters (Appendix G, pp. 736-737; Figure 1, p. 746). Transects were not located within pre-determined designated ingress and egress areas for the sprayer. Along with the plant effect transects located immediately adjacent to the treated field, eight upwind control areas were identified and evaluated for plant height.

Plant effects from volatility were assessed by isolating a portion of the non-tolerant soybean crop immediately adjacent to the treated areas using plastic sheeting (transect covers) during the application period to prevent exposure to spray drift (Appendix G, pp. 736-737; Figures 1 and 2, pp. 746-747). The non-tolerant soybeans that were covered during the application were used to assess effects to plant height and visual symptomology from dicamba volatility. The plastic covers were intended to remain in place for approximately 30 min post-application before permanent removal for the remainder of the study. The actual time the plants remained covered ranged from 10:53 am to 12:37 pm (approximately 1 hour and 45 minutes).

9. Sample Handling and Storage Stability

PUF sorbent tube and deposition filter paper samples were handled with clean nitrile gloves (Appendix B, pp. 94-95). PUF sorbent tubes and filter paper samples were placed in pre-labeled conical tubes. All samples were stored in coolers containing dry ice or freezers at -20°C prior to shipment and were shipped in coolers containing dry ice to the analytical testing facility. Spray area (application monitoring) samples were kept separate from other samples and were stored and shipped in a cooler containing dry ice until final transfer to storage at approximately -20°C at the analytical test site. Tank mix samples were stored and shipped in a cooler under ambient conditions. Field spikes and transit stability samples were stored in coolers containing dry ice. Samples were shipped by overnight courier to Eurofins, Columbia, Missouri.

All field collected PUF and filter paper samples were extracted within 9 and 12 days after collection, respectively. All field exposed QC and transit stability samples were extracted within 9 days after fortification. Stability of dicamba on PUF and filter paper samples was demonstrated for at least 78 and 85 days, respectively, during frozen storage in a stability study (Maher 2016). All PUF and filter paper samples were analyzed within 3 and 16 days of extraction, respectively, which study authors indicate is within the demonstrated stability (Appendix C, p. 245-246).

10. Analytical Methodology

- Sampling Procedure and Trapping Material: Flux monitoring equipment consisted of PUF collectors housed in ¾ inch diameter PVC pipes (Appendix B, p. 96). SKC AirChek 52 air sampling pumps were used, covered with plastic bags to protect them from precipitation. Pumps were calibrated to a flow rate of 2.950-3.050 L/min. Spray drift deposition collectors consisted of Whatman #1 15 cm diameter filter papers (Appendix B, p. 98).

- Extraction method: The contents of the PUF sorbent tubes were extracted using methanol containing stable-labeled internal standard (Appendix C, pp. 304-327). The sample was fortified with internal standard, a grinding ball was added to the tube, and 29.8 mL of methanol was added. The sample tubes were capped and agitated on a high-speed shaker (Geno/Grinder®) for 1200 cycles per minute for 30 minutes. The cap was removed, and a 1.5 mL aliquot was transferred to a 0.45 µm polypropylene 96-well filter plate with a clean polypropylene plate positioned below the filter plate (Appendix C, pp. 328-329). The sample was evaporated to dryness under nitrogen at 50°C. The sample was reconstituted with 0.150 mL of 25% methanol in water. The sample was mixed and analyzed by LC-MS/MS with electrospray ionization in negative ion mode (Appendix C, p. 245).

  The filter paper samples were extracted using methanol containing stable-labeled internal standard (Appendix C, pp. 332). The sample was fortified with internal standard, a grinding ball was added to the tube, and 29.9 mL of methanol was added. The sample tubes were capped and agitated on a high-speed shaker (Geno/Grinder®) for 1200 cycles per minute for 5 minutes. The tubes were then placed in a ≤10°C centrifuge (4500 xg for 5 minutes) and spun to clear suspended materials from the liquid column and form a solid pellet. The cap was removed and a 0.35 mL aliquot was transferred to a clean 96-well filter plate with a clean, glass-lined polypropylene plate positioned below the filter plate (Appendix C, pp. 339). The plates were then placed in a ≤10°C centrifuge (1500 xg for 1 minute) and spun until liquid passed through the plate. The solution was analyzed by LC-MS/MS with electrospray ionization in negative ion mode (Appendix C, p. 332).

- Method validation (Including LOD and LOQ): Method validation was achieved by fortifying 18 replicate fortification samples at each of three fortification levels (0.3 ng/PUF, 3 ng/PUF, and 60 ng/PUF; Appendix C, pp. 322-326). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level for both primary and secondary ion transitions. Average recoveries for primary ion transitions were 89%, 94%, and 90% at 0.3, 3, and 60 ng/PUF, respectively. Average recoveries for secondary ion transitions were 93%, 97%, and 98% at 0.3, 3, and 60 ng/PUF, respectively. No independent laboratory validation was provided. For primary ion transitions, the LOQ during method validation was 0.30 ng/PUF and the LOD was 0.094 ng/PUF (Appendix C, p. 323). For secondary ion transitions, the LOQ during method validation was 0.30 ng/PUF and the LOD was 0.065 ng/PUF. During the study, the LOQ was 1.0 ng/PUF (p. 19).

  Method validation was achieved by fortifying 6 replicate fortification samples at each of three fortification levels (0.005, 0.10, and 4.8 µg/filter paper; Appendix C, pp. 346). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level for both primary and secondary ion transitions. Average recoveries were 81%, 117%, and 104% at 0.005, 0.10, and 4.8 µg/filter paper, respectively. No independent laboratory validation was provided, although results from Field Deposition Study REG-2015-004 confirmed the results. The LOQ during method validation was 0.005 µg/filter paper (Appendix C, p. 332). During the study, the LOQ was 0.005 µg/filter paper (p. 19).

- Instrument performance: Calibration standards were prepared at concentrations ranging from 0.15 to 75 ng/PUF (Appendix C, p. 310). Concentrations were 0.15, 0.225, 0.3, 0.75, 1.5, 2.25, 3, 7.5, 15, 22.5, 30, and 75 ng/PUF. Analyst® software was used to derive the calibration curve using a weighted linear curve (1/x; Appendix C, pp. 316 and 369).

  Calibration standards were prepared at concentrations ranging from 0.0015 to 6 µg/filter paper (Appendix C, p. 337). Concentrations were 0.0015, 0.003, 0.0075, 0.015, 0.03, 0.075, 0.15, 0.3, 0.75, 1.5, 3, and 6 µg/filter paper. Analyst® software was used to derive the calibration curve using a weighted linear curve ($1/x^2$; Appendix C, pp. 357).

11. Quality Control for Air Sampling

Lab Recovery: 16 of 27 laboratory spike recoveries are within the acceptable range of 90-110% (Appendix C, pp. 372-373). All laboratory spike recoveries are within the range of 76-115%. Laboratory spike samples were prepared at fortification levels of 1 ng/PUF (12 samples), 60 ng/PUF (12 samples), and 500 ng/PUF (3 samples). Average recoveries were 89%, 106%, and 106% at 1 ng/PUF, 60 ng/PUF, and 500 ng/PUF, respectively (Appendix C, p. 373).

Field blanks: Two pre-application samples were collected from the center of the test plot from 10:13 to 16:30 on September 10, 2019, the day before application (Appendix B, pp. 96-97). Dicamba was detected in both pre-application samples at concentrations greater than the LOD but less than the LOQ (0.687 ng/PUF and 0.312 ng/PUF; Appendix B, p. 104 and Appendix B, Table 6, p. 256).

All six control samples from field spike analyses also contained detectable dicamba at 0.389 ng/PUF to 1.61 ng/PUF (Appendix B, p. 104 and Appendix C, Table 8, p. 263). Five of the six samples contained dicamba at levels less than the LOQ (1 ng/PUF).

Field Recovery: Nine 6-hour and twelve 12-hour field spike samples were collected at concentration levels of 3, 10, and 30 ng/PUF. A total of six field spikes were prepared at each concentration level. Most field spike recoveries were within the acceptable range with overall recoveries of 101% to 145% at 3 ng/PUF, 98% to 111% at 10 ng/PUF, and 97% to 108% at 30 ng/PUF (Appendix B, p. 104 and Appendix B, Table 8, p. 263).

Travel Recovery: Three transit stability PUF samples were fortified at 30 ng/PUF and placed on dry ice along with three unfortified control samples (Appendix B, pp. 100-101, 104). Dicamba was detected in one of the three control samples at a level less than the LOQ (0.399 ng/PUF). The range of recoveries from the fortified samples was from 94% to 102%.

Breakthrough: Laboratory spike samples that were fortified at 60 ng/PUF had recoveries ranging from 96% to 115% (Appendix C, pp. 372-373). Laboratory spike samples that were fortified at 500 ng/PUF had recoveries ranging from 104% to 109%. The highest dicamba amount measured on a PUF sample (excluding laboratory and field spikes) was 229.4 ng/PUF (Appendix C, pp. 376-385) which is *ca.* 46% of the highest fortification level, indicating that dicamba loss due to breakthrough is unlikely.

12. Quality Control for Deposition Sampling

Lab Recovery: 45 of 60 laboratory spike recoveries are within the acceptable range of 90-110% (Appendix C, pp. 390-393). Twelve recoveries spiked at 0.005 µg/filter and 3 recoveries spiked at 5 µg/filter were outside the range. All laboratory spike recoveries are within the range of 85-112%. Laboratory spike samples were prepared at fortification levels of 0.005 µg/filter (27 samples), 5 μg/filter (27 samples), and 50 μg/filter (6 samples). Average recoveries were 95%, 104%, and 103% at 0.005 μg/filter, 5 μg/filter, and 50 μg/filter, respectively (Appendix C, p. 265).

Travel Recovery: Five transit stability filter paper samples were fortified at 0.05 μg/filter paper and placed on dry ice along with five unfortified control samples (Appendix C, p. 162, 421). Dicamba was not detected in the control samples. The range of recoveries from the fortified samples was from 95% to 98%.

13. Application Verification

Four application monitoring sampling stations, each consisting of four 12.5 cm diameter Whatman #3 filter paper samples, were positioned in the spray area (Appendix B, p. 96). The stations were positioned to capture different portions of the spray boom and different spray nozzles. The average recovery relative to the target application rate was 97.23% (Appendix B, p. 104; Appendix B, Table 15, p. 127; and Appendix C, p. 359).

Spray application rates were automatically maintained by the sprayer using a variable rate controller (Appendix B, p. 102). The application rate was assumed to be 100% of the target rate, and pass times were not used to calculate an application rate. The actual application rate calculated by Climate FieldView™ software was 103% of the target rate (Appendix B, Table 3, p. 110).

Tank mix samples were also collected and analyzed to verify the amount of dicamba present in the tank mix (Appendix B, p. 95).

14. Deposition and Air Concentration Modeling

Off-target air concentrations and deposition were calculated based on the calculated flux rates and relevant meteorological data. Study authors used U.S. EPA's AERMOD model (version 18081) to estimate deposition and the Probabilistic Exposure and Risk model for Fumigants (PERFUM2, version 2.5) to estimate air concentrations (Appendix E, p. 610). Three sets of estimates were calculated, using meteorological data for Raleigh, North Carolina; Peoria, Illinois; and Lubbock, Texas (Appendix E, p. 611). The reviewer used PERFUM version 3.2 to estimate air concentrations using the same meteorological data.

The maximum flux predicted by any method for each period was chosen to represent that period. Periods were then mapped onto hours of the day (1- 24), where the maximum flux rate for each hour was then chosen to represent that hour, regardless of the day from which it was collected. In cases where two periods occurred in a single hour, a weighted average of the flux rates was used. The 24-hour flux profile for the first two days were used as inputs for PERFUM2 and the average flux rate and as adjustment factors for input into AERMOD. The reviewer and study author flux rates were slightly different, particularly where weighted averaging occurred. However, they did not impact the overall modeling conclusions.

Wet and dry deposition estimates were made at 10 distances from the field (5, 10, 20, 30, 40, 50, 75, 100, 125, and 150 m; Appendix E, pp. 613). For the fluxes from the bare ground plot at a distance of 5 m from the edge of the field, maximum 24-hour total (dry+wet) deposition ranged from 9.67 to 12.76 $\mu g/m^2$ (Appendix E, Table 7, pp. 625-626). 90^{th} percentile total deposition ranged from 3.71 to 5.02 $\mu g/m^2$.

Modeled dicamba air concentrations were calculated at 4 distances from the field (5, 10, 25, and 50 m; Appendix E, pp. 612-613). Modeled 95^{th} percentile 24-hour air concentrations ranged from 16.7 to 25.2 ng/m^3 at 5 m from the edge of the treated field and 11.7 to 17.1 ng/m^3 at 50 m from the edge of the field.
Reviewer estimates for 24-hour total deposition were slightly higher than those of the study authors, with the 90^{th} percentile at 5 m from the field ranging from 8.68 to 12.8 $\mu g/m^2$. Reviewer estimates for 24-hour air concentrations were slightly higher, ranging from 39 to 60 ng/m^3 at 5 m from the edge of the treated field. This was primarily due to the fact that the reviewer retained Period 6 flux rates, while study authors removed them from consideration. The reviewer also conducted modeling analysis for Little Rock, Arkansas, Nashville, Tennessee, and Springfield, Missouri, attempting to capture modeling results representative of soybean growing regions in Arkansas, Tennessee, and Missouri. Air concentration modeling results were slightly lower (32-44 ng/m^3), but comparable, than those achieved for the North Carolina, Illinois, and Texas modeling results.

II. Results and Discussion

A. Empirical Flux Determination Method Description and Applicability

Indirect Method

The indirect method, commonly referred to as the "back calculation" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the indirect method, air samples are collected at various locations outside the boundaries of a treated field. Meteorological conditions, including air temperature, wind speed, and wind direction, are also collected for the duration of the sampling event. The dimensions and orientation of the treated field, the location of the samplers, and the meteorological information are used in combination with the AERMOD dispersion model (Version 18081) and a unit flux rate of 0.001 $g/m^2 \cdot s$ to estimate concentrations at the sampler locations. Since there is a linear relationship between flux and the concentration at a given location, the results from the AERMOD model runs are compared to those concentrations actually measured, and a regression is performed, using the modeled values along the x-axis and the measured values along the y-axis. If the linear regression does not result in a statistically significant relationship, the regression may be rerun forcing the intercept through the origin, or the ratio of averages between the monitored to modeled concentrations may be computed, removing the spatial relationship of the concentrations. The indirect method flux back calculation procedure is described in detail in Johnson et al., 1999.

Study authors used a similar analysis to obtain flux rates. However, if, after regression analysis, the linear regression did not result in a statistically significant relationship, instead of rerunning the regression by forcing the intercept through zero, study authors removed the spatial relationship by sorting both the measured and modeled air concentrations (independently) in ascending order, then redoing the regression, with the final flux estimate calculated as the slope of this alternative regression multiplied by the nominal flux. If the sorted regression was also not statistically significant, study authors multiplied the ratio of the sum of the measured concentrations to the sum of the modeled concentrations by the nominal flux to get the final flux estimate.

Aerodynamic Method

The aerodynamic method, also referred to as the "flux-gradient" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the aerodynamic method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from 0.5 to 10 feet. Likewise, temperature and wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the aerodynamic method is Thornthwaite-Holzman Equation, which is shown in the following expression:

Equation 1
$$P = \frac{k^2(\Delta\bar{c})(\Delta\bar{u})}{\phi_m \phi_p [\ln\left(\frac{z_2}{z_1}\right)]^2}$$

where P is the flux in units of $\mu g/m^2 \cdot s$, k is the von Karman's constant (dimensionless ~0.4), $\Delta\bar{c}$ is the vertical gradient pesticide residue concentration in air in units of $\mu g/m^3$ between heights z_{top} and z_{bottom} in units of meters, $\Delta\bar{u}$ is the vertical gradient wind speed in units of m/s between heights z_{top} and z_{bottom}, and ϕ_m and ϕ_p are the momentum and vapor stability correction terms respectively. Following the conditions expected in the neutrally stable internal boundary layer characterized by an absence of convective (buoyant) mixing but mechanical mixing due to wind shear and frictional drag, a log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. The adjusted values of the concentration, temperature, and wind speed from this regression is incorporated into Equation 1 to arrive at Equation 2 which is ultimately used to compute the flux.

Equation 2
$$Flux = \frac{-(0.42)^2(c_{ztop} - c_{zbottom})(u_{ztop} - u_{zbottom})}{\phi_m \phi_p \ln\left(\frac{z_{top}}{z_{bottom}}\right)^2}$$

where ϕ_m and ϕ_p are internal boundary layer (IBL)stability correction terms determined according to the following conditions based on the calculation of the Richardson number, R_i:

Equation 3
$$R_i = \frac{(9.8)(z_{top} - z_{bottom})(T_{ztop} - T_{zbottom})}{\left[\left(\frac{T_{ztop} + T_{zbottom}}{2}\right) + 273.16\right] + (u_{ztop} - u_{zbottom})^2}$$

where T_{ztop} and $T_{zbottom}$ are the regressed temperatures at the top and bottom of the vertical profile in units of °C.

if $R_i > 0$ (for Stagnant/Stable IBL)
$\phi_m = (1+16R_i)^{0.33}$ and $\phi_p = 0.885(1+34R_i)^{0.4}$

if $R_i < 0$ (for Convective/Unstable IBL)
$\phi_m = (1-16R_i)^{-0.33}$ and $\phi_p = 0.885(1-22R_i)^{-0.4}$

The minimum fetch requirement that the fetch is 100 times the highest height of the air sampler for this method to be valid was satisfied for all but sampling periods 3, 5, and 8. However, the fetch distances for these periods (147-149 m) was just slightly below the minimum height requirement (150 m), so the impact of not meeting this requirement is not considered significant. The aerodynamic method used to estimate flux and related equations are presented in Majewski et al., 1990.

Integrated Horizontal Flux Method

The integrated horizontal flux method, also referred to as the "mass balance" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the integrated horizontal flux method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from approximately 0.5 to 5 feet. Likewise, wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the air concentration and wind speed following the log law relationships for the atmospheric boundary layer. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the integrated horizontal flux method is the following expression:

Equation 4 $$P = \frac{1}{x}\int_{Z_0}^{Z_p} \overline{c}\overline{u}\,dz$$

where P is the volatile flux in units of µg/m^2·s, $\overline{c}$ is the average pesticide residue concentration in units of µg/m^3 at height Z in units of meters, $\overline{u}$ is the wind speed in units of m/s at height Z, x is the fetch of the air trajectory blowing across the field in units of meters, Z_0 is the aerodynamic surface roughness length in units of meters, Z_p is the height of the plume top in units of meters, and dz is the depth of an incremental layer in units of meters. Following trapezoidal integration, equation 3 is simplified as follows in equation 5 (Yates, 1996):

Equation 5 $$P = \frac{1}{x}\sum_{Z_0}^{Z_P}(A * Ln(z) + B) * (C * Ln(z) + D)dz$$

where A is the slope of the wind speed regression line by ln(z), B is the intercept of the wind speed regression line by ln(z), C is the slope of the concentration regression by ln(z), D is the intercept of the concentration regression by ln(z), z is the height above ground level. Z_p can be determined from the following equation:

Equation 6 $$Z_P = \exp\left[\frac{(0.1 - D)}{C}\right]$$

The minimum fetch requirement of 20 meters for this method to be valid was satisfied at all times. The surface of the field was bare and study authors estimated surface roughness lengths of 0.0001 to 0.04, which is below the maximum surface roughness length requirement of 0.1 meters for the method to be valid.

B. Temporal Flux Profile

The flux determined from the registrant and reviewer for each sampling period after the application is provided in **Tables 6** and **7**. The pH of the tank mix was 4.82 prior to application.

Table 6. Field volatilization flux rates of dicamba obtained in study – Indirect Method

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer (µg/m²·s)	Notes	Registrant (µg/m²·s)	Notes
1	9/11/19 11:54 – 16:03	4:09	0.002787	Regression	0.002787	A
2	9/11/19 15:40 – 19:07	3:27	0.000852	Regression	0.000852	A
3	9/11/19-9/12/19 18:44 – 8:14	13:30	0.000088	Regression, no intercept	0.000162	B
4	9/12/19 7:44 – 19:04	11:20	0.000191	Regression, no intercept	0.000166	A
5	9/12/19-9/13/19 18:44 – 7:32	12:48	0.000038	Regression, no intercept	0.000084	B
6	9/13/19 7:14 – 18:09	10:55	0.000083	Regression	0.000083	A
7	9/13/19-9/14/19 17:46 – 7:28	13:42	0.000004	Regression	0.000004	A
8	9/14/19 7:13 – 18:00	10:47	0.000027	Regression, no intercept	0.000021	C
9	9/14/19-9/15/19 17:41 – 7:32	13:51	0.000007	Regression	0.000007	A
10	9/15/19 7:13 – 17:55	10:42	0.000049	Regression	0.000100	C
11	9/15/19-9/16/19 17:39 – 7:30	13:51	0.000020	Regression, no intercept	0.000007	C
12	9/16/19 7:12 – 17:53	10:41	0.000171	Regression	0.000171	A
13	9/16/19-9/17/19 17:38 – 7:26	13:48	0.000007	Regression	0.000017	C

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer (µg/m²·s)	Notes	Registrant (µg/m²·s)	Notes
14	9/17/19 7:12 – 17:53	10:41	0.000020	Regression	0.000038	C
15	9/17/19-9/18/19 17:37 – 7:27	13:50	0.000006	Regression	0.000006	A

Data obtained from Appendix B, Table 6, pp. 113-114 and Appendix D, Table 6, p. 555 of the study report.
Notes
A The spatial regression method was used to calculate the flux estimate for the sampling period.
B The ratio method was used to calculate the flux estimate for the sampling period.
C The sorted regression method was used to calculate the flux estimate for the sampling period.

Table 7. Field volatilization flux rates of dicamba obtained in study – Integrated Horizontal Flux and Aerodynamic Methods

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer (µg/m²·s)	Registrant (µg/m²·s)	Empirical Flux Determination Method*	Notes
1	9/11/19 11:58 – 15:51	3:53	0.001555 0.007064	0.001566 0.007062	IHF AD	
2	9/11/19 15:58 – 18:44	2:46	0.000598 0.001983	0.000601 0.001983	IHF AD	
3	9/11/19-9/12/19 18:49 – 7:55	13:06	0.000087 0.000073	0.000087 0.000072	IHF AD	
4	9/12/19 7:56 – 18:53	10:57	0.000223 0.000134	0.000224 0.000134	IHF AD	
5	9/12/19-9/13/19 18:54 – 7:25	12:31	0.000023 0.000020	0.000023 0.000020	IHF AD	
6	9/13/19 7:25 – 17:52	10:27	0.001113 0.008739	0.001120 0.008745	IHF AD	A
7	9/13/19-9/14/19 17:53 – 7:22	13:29	0.000013 0.000046	0.000013 0.000045	IHF AD	
8	9/14/19 7:23 – 17:49	10:26	0.000030 0.000038	0.000030 0.000038	IHF AD	
9	9/14/19-9/15/19 18:01 – 7:19	13:18	0.000003 0.000005	0.000003 0.000005	IHF AD	
10	9/15/19 7:20 – 17:44	10:24	0.000024 0.000277	0.000024 0.000276	IHF AD	
11	9/15/19-9/16/19 17:47 – 7:18	13:31	0.000008 0.000012	0.000008 0.000011	IHF AD	
12	9/16/19 7:22 – 17:41	10:19	NC NC	NC NC	IHF AD	B
13	9/16/19-9/17/19 17:42 – 7:18	13:36	0.000011 0.000010	0.000011 0.000010	IHF AD	

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer (µg/m²·s)	Registrant (µg/m²·s)	Empirical Flux Determination Method*	Notes
14	9/17/19 7:21 – 17:44	10:23	0.000096 0.000012	0.000097 0.000012	IHF AD	
15	9/17/19-9/18/19 17:45 – 7:18	13:33	0.000004 0.000009	0.000004 0.000009	IHF AD	

Data obtained from Appendix B, Table 6, p. 113; Appendix D, Table 8, p. 557; and Appendix D, Table 10, p. 560 of the study report.
NC indicates not calculated.
*Methods legend: AD = Aerodynamic Method, IHF = Integrated Horizontal Flux.
Notes
A Based on comparison of perimeter and center mast sample concentrations and the results of the indirect method, the flux calculated for this sampling period was considered anomalous (Appendix D, Table 8, p. 557 and Appendix D, Table 10, p. 560).
B No flux was calculated for this period due to a reversed concentration gradient (Appendix D, Table 8, p. 557 and Appendix D, Table 10, p. 560).

Due to a reversed concentration gradient on the central mast during period 12 (i.e., concentrations increased with height), no flux was calculated for this period using the integrated horizontal flux or aerodynamic methods. The dicamba flux calculated for period 6 using the integrated horizontal flux and aerodynamic methods was high. The registrant concluded that based on a comparison of perimeter and center mast sample concentrations and the results of corresponding flux estimates using the indirect method, the flux calculated for period six using the integrated horizontal flux and aerodynamic methods was anomalous (Appendix D, pp. 538-539). The reviewer could not identify anything anomalous with the concentration, temperature, or wind speed profiles that would preclude the use of the flux rate for period 6 for modeling purposes.

The maximum flux rate calculated by the indirect method occurred during the initial sampling period after application. The maximum flux rate was 0.002787 $\mu g/m^2 \cdot s$. The maximum flux rates for the integrated horizontal flux and aerodynamic methods were 0.001555 $\mu g/m^2 \cdot s$ (Period 1) and 0.008739 $\mu g/m^2 \cdot s$ (Period 6), respectively. The maximum flux rate for Period 1 for the aerodynamic method was 0.007064 $\mu g/m^2 \cdot s$.

R-squared values for the linear regressions of modeled and measured air concentrations in the indirect method ranged from 0.16 to 0.91. The lowest R-squared values were 0.16, 0.18, and 0.19 for periods 13, 14, and 10, respectively. Study authors used spatial regression to estimate flux during periods 1, 2, 4, 6, 7, 9, 12, and 15, the ratio method to estimate flux during periods 3 and 5, and the sorted regression method for periods 8, 10, 11, 13, and 14. The reviewer used the spatial regression method for periods 1, 2, 6, 7, 9, and 12 through 15, while using regression forcing the intercept through zero for periods 3 through 5, 8, and 11.

R-squared values in log-linear vertical profiles of wind speed were generally high with all R-squared values ≥0.970. R-squared values in log-linear vertical profiles of concentration were low for periods 14 (0.496), 12 (0.659), and 11 (0.679). R-squared values in log-linear vertical profiles of temperature were between 0.722 and 0.985 with the exception of periods 15 (0.073) and 13 (0.365).

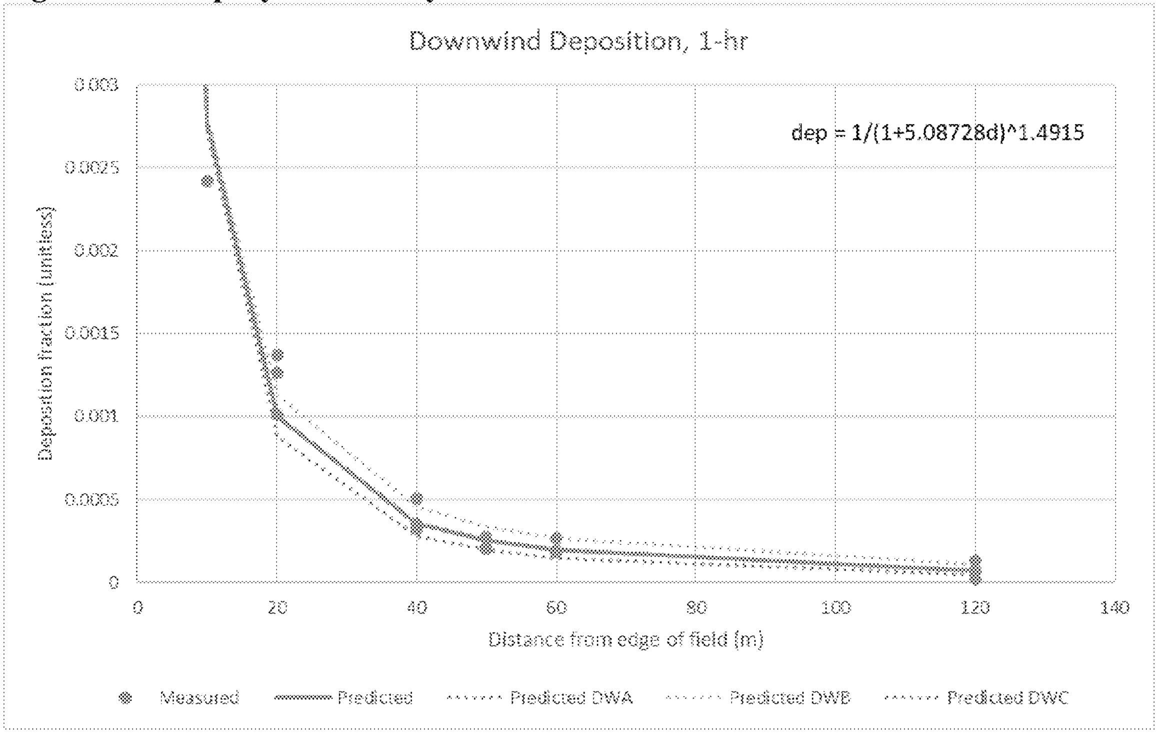
C. Spray Drift Measurements

Spray drift measurements indicated that dicamba residues were detected at a maximum fraction of the applied deposition of 0.012640 in downwind samples (Appendix F, Table 1, pp. 659-672) at 3 m from the treated field. Dicamba residues were not detected above the NOAEC (2.6×10^{-4} lb ae/A, or a deposition fraction of 5.2×10^{-4}) in any of the upwind, left wind, or right wind samples during any of the sampling periods. **Figure 4** depicts the deposition fractions and the reviewer-predicted spray drift curve for the three downwind transects within the first hour after application.
To develop the deposition curves, data were fit to a modified Morgan-Mercer-Floden function, similar to how spray drift deposition estimates were derived for the AgDRIFT, ground application model.

$$f = \frac{1}{(1 + ad)^b}$$

where f is the fraction of the application rate at distance d (m). The fitted parameters are a and b, where a is the 'slope' parameter and b is the curvature of the function. Typically, the fitted equation would include a term to account for the deposition from each swath. However, as the path of application was not always perpendicular to the deposition collectors, this term was removed from the equation. The coefficients were obtained by fitting the field data for the various transects.

Figure 4 Spray Drift Analysis for Downwind Transects – 1 Hour



ED_005172C_00001231-00022

Study authors derived deposition curves using four non-linear regression models for each transect (Appendix F, p. 654). For samples collected within the first hour of application, the best fit models for the downwind transects were the exponential with intercept model (downwind transects A & B) and the power with coefficient and intercept model (downwind transect C; Appendix F, Table 2, p. 673). The curves were similar to those generated by the reviewer.

Estimated distances from the edge of the field to reach NOAEC for soybeans (2.6×10^{-4} lb ae/A, or a deposition fraction of 5.2×10^{-4}) was 31 m (27.6 to 36.1 m for all three transects) in the downwind direction using the reviewer-developed curves and ranged from 23.5 to 41.6 m in the downwind direction for the study author developed curves.

D. Plant Effects Results

Spray Drift + Volatility Exposure Transects

Plant Height

The reviewer found significant inhibitions of plant height along downwind (DW) transects. The reviewer evaluated each of the observed transects independently using logistic regression methods in Excel (Figures 6, 8 & 10). The best fit regression (as indicated by the R^2) for each transect were used to estimate the distance at which a 5% reduction in plant height would be predicted based on the comparison to the mean plant height from control plots. Table 6b provides the estimated distances to 5% reduction in plant height for each transect. The furthest distances were estimated for transects in the DW transect areas, reaching out to distances of 17.5 to 62 meters (57 to 203 feet).

A major uncertainty in the implementation of this study was that the measurements of plant height were not consistently taken from the same individual plants over the course of the successive sampling events. While the study authors indicate that the initial plot distances were selected to reduce variability in plant height at the start of the study, it is unclear how the transects relate to the rest of the field, and more importantly how other plants in the plot were responding as compared to those that were selected "non-systematically" for measurement of plant height. No discussion was provided to explain how the plants were selected such to prevent selection of the healthiest looking plants from a plot. This uncertainty may contribute to underestimation of effects and therefore underestimation of off-field distance estimates.

Another major uncertainty regarding plant height is the late season application and observation of plant effects. There was relatively low plant growth between 14-DAT and 28-DAT in the controls which indicates the potential impact of the late season. The impact of this on the results is unknown.

Visual Signs of Injury (VSI)

Visible symptomology was reported, but the specific phytotoxic symptoms were not detailed for the transects. For the drift study, two of the downwind transects, two of the left-side wind transects, and the northeast transect showed a dose-response relationship between percent of visual symptoms and distance to the treatment field. For these transects, linear, logistic and polynomial regression methods in Excel to estimate the distance to the point where 10% VSI would be predicted (Figures 7, 9 & 11). The furthest distances to 10% VSI were consistent with the transects that showed significant effects on plant height and ranged from 17 meters to greater than 62 meters (Table 6b).

Volatility Exposure (covered) Transects

Plant height measures and distances estimated with logistic regression, indicate that impacts to plant height were significantly less than observed along the uncovered transects. Effects were observed along the DWC and LWA transects with a maximum 5% effect distance estimated at 9.9 meters (52 feet Table 6b). Visual signs of injury were also observed along the DW transects with maximum distance to 10%VSI out to 20.1 meters (DWB; Table 6b)

Table 6b. Estimated distance to 5% reduction in plant height and visual signs of injury.

Exposure Pathway	Spray Drift + Volatility (uncovered transects)		Volatility (covered transects)	
Transect	Distance to 5% Height (meters)	Distance to 10% VSI (meters)	Distance to 5% Height (meters)	Distance to 10% VSI (meters)
DWA	17.5[b]	57.0[a]	<3 [d]	13.6[b]
DWA-D	20.9[a]	11.7[a]	NA	NA
DWB	29.0[a]	48.0[a]	<5	20.1[b]
DWC	62.0[b]	87.5[a]	9.9[a]	10.6[a]
DWC-D	20.2[b]	19.7[a]	NA	NA
LWA	<3[d]	<3 [d]	<20 [d]	<3 [d]
LWB	<20 [d]	<10 [d]	<3 [d]	<3 [d]
RWA	<3 [d]	<3 [d]	<3 [d]	<3 [d]
RWB	<3 [d]	26.9[c]	<10 [d]	<5 [d]
UWA	<20 [d]	<3 [d]	<3 [d]	<3 [d]
UWB	<3 [d]	<3 [d]	<3 [d]	<3 [d]
UWB-D	<20 [d]	<3 [d]	NA	NA

[a] distance estimated with logistic regression
[b] distance estimated with polynomial regression
[c] distance estimated with linear regression
[d] distance estimated visually

Figure 6: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "Downwind Transects".

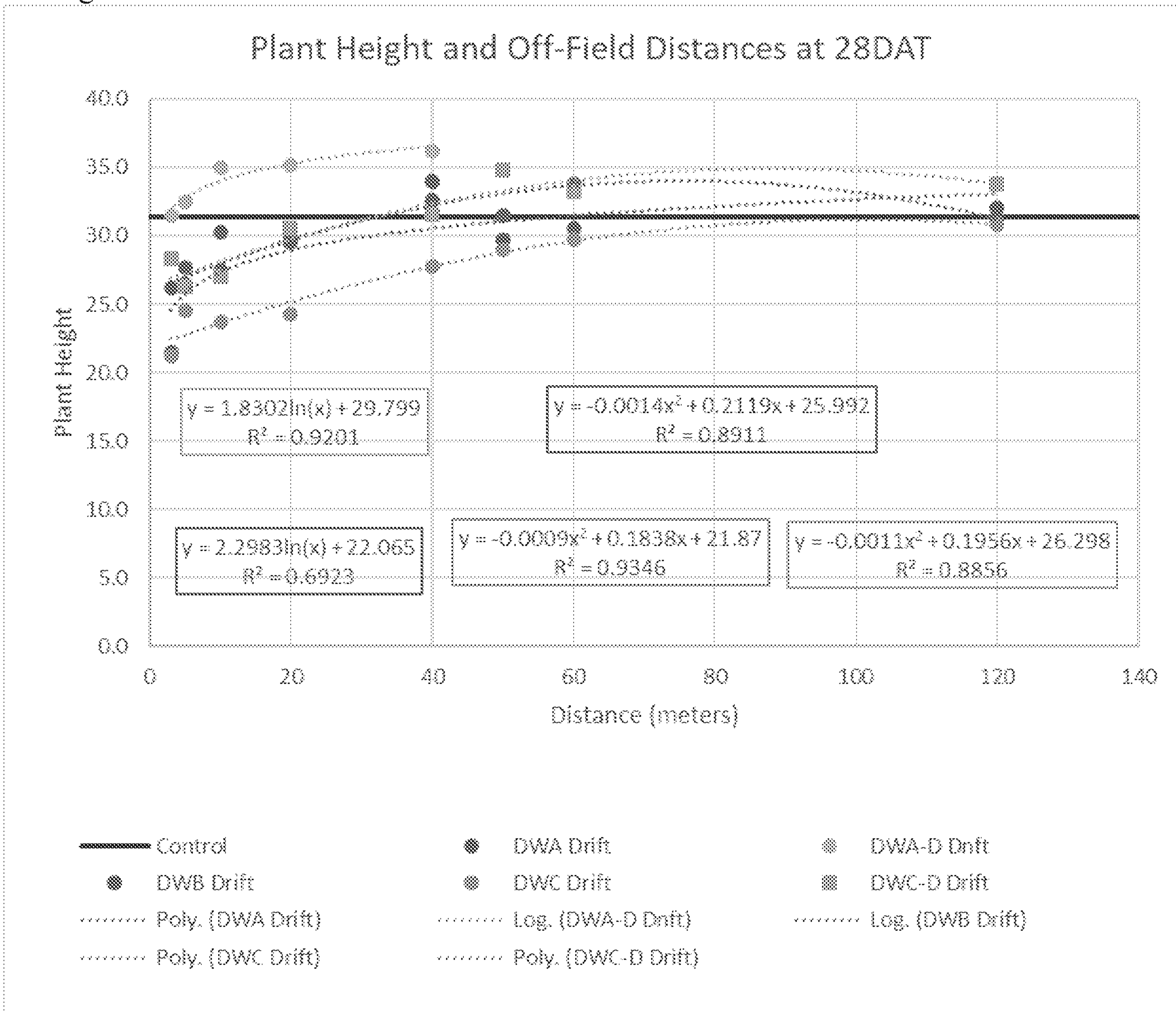


Figure 7: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "Downwind Transects".

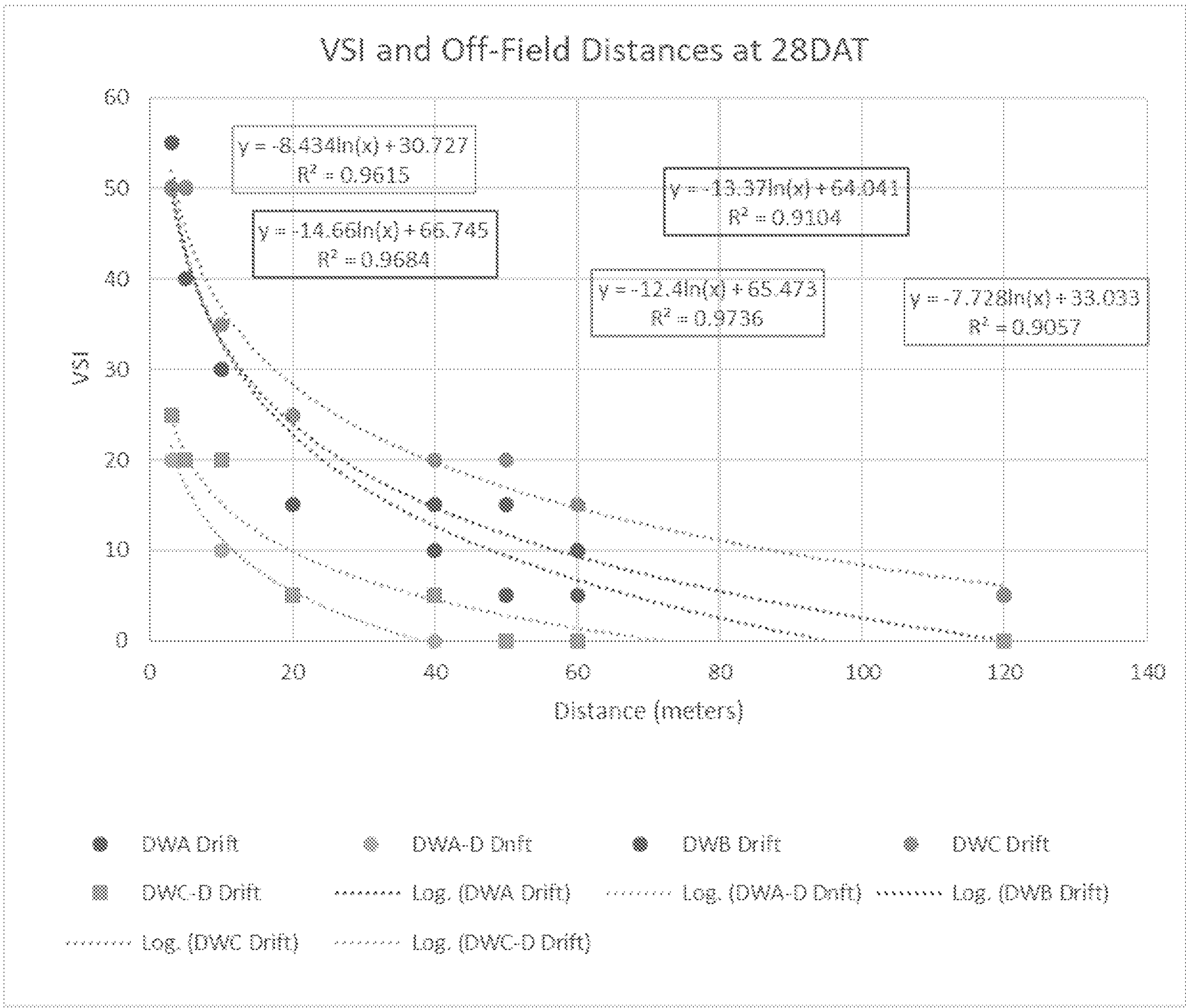


Figure 8: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for DW covered transects.

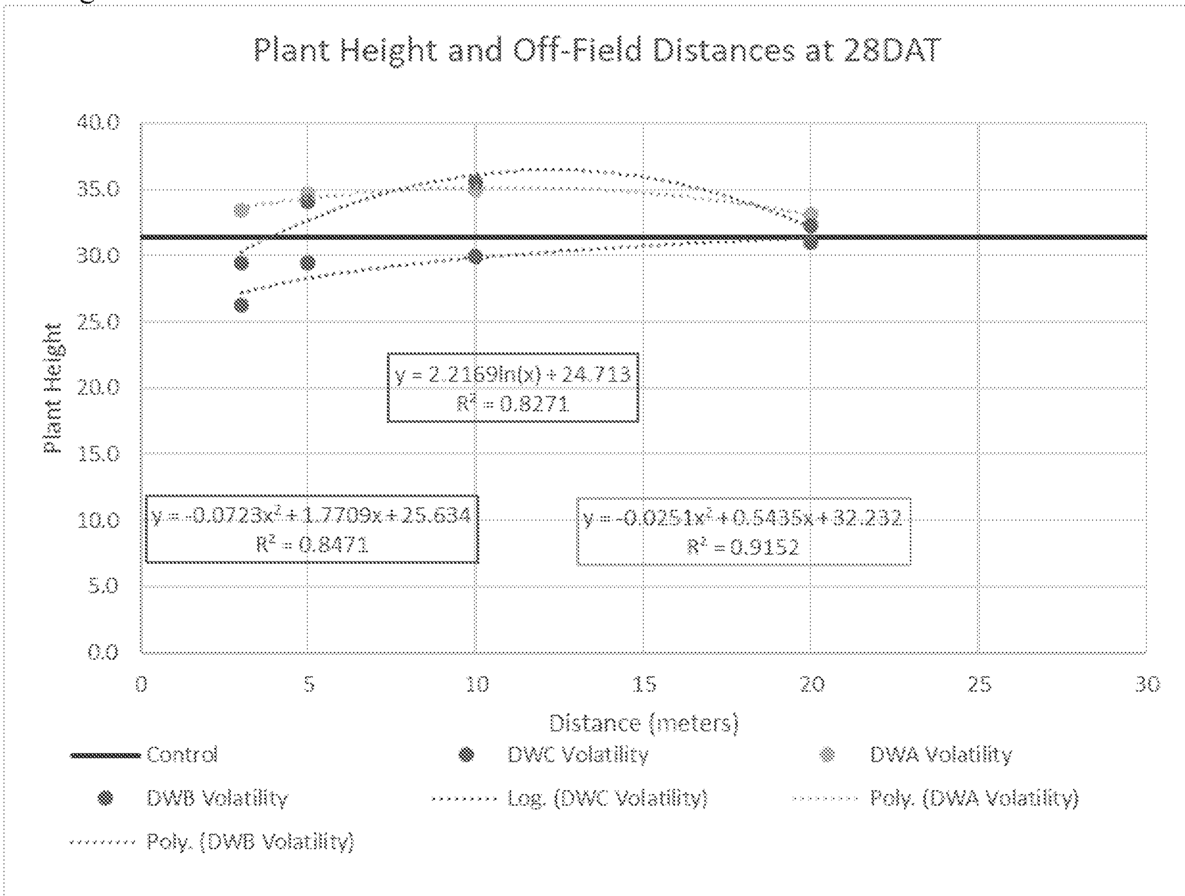
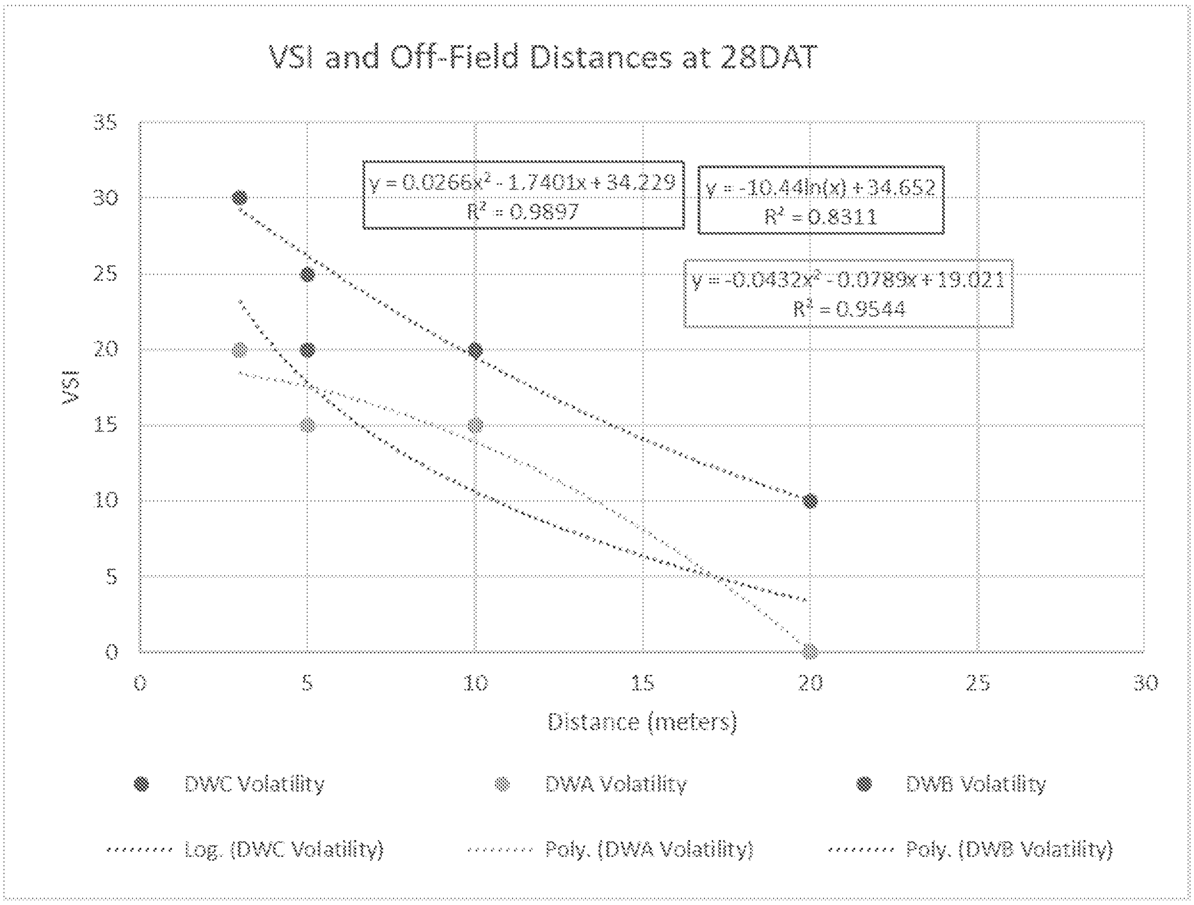


Figure 9: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for DW covered transects.



III. Study Deficiencies and Reviewer's Comments

1. The registrant used a different approach to calculate Z_p, the top of the concentration plume, than that recommended by EPA when calculating volatilization flux rates using the Integrated Horizontal Flux method (Appendix D, pp. 533-534). The registrant used:

$$Z_p = \exp\left(\frac{-D}{C}\right)$$

C and D are the slope and intercept of the log-linear concentration regression and removed the 0.1 from the equation. The 0.1 represents the concentration at the top of the plume, which is a carryover from the use of this technique for estimating flux rates for fumigants, which typically have much higher concentrations than those anticipated for semi-volatile chemicals like dicamba. The revised equation is acceptable to the reviewer and does not significantly impact the estimate of flux rates.

2. When conducting the indirect flux rate analysis, study authors removed samples from the analysis when the dicamba was detected below the LOD (0.3 ng/PUF) but retained samples that had no observable peak or observed residues. Samples below the LOD should be retained as well.

3. The study was conducted in compliance with U.S. EPA Good Laboratory Practice requirements with exceptions related to pesticide and crop history, soil taxonomy, test site observations, slope estimates, and study weather data (p. 4).

4. Dicamba was detected in both pre-application samples and all six non-fortified field exposed samples at levels greater than the LOD. Detected levels ranged from 0.312 ng/PUF to 1.61 ng/PUF (Appendix C, Table 6, p. 256 and Appendix C, Table 8, p. 263). In seven of the eight samples, levels were less than the LOQ of 1 ng/PUF.

5. The first air monitoring period started after the conclusion of application.

6. Analytical method validation was performed, but the method was not independently validated. A method validation study should be completed from an independent laboratory separate from and prior to the analysis of the test samples to verify the analytical methods.

7. Soil was characterized (Appendix B, pp. 94, 103, and Appendix B, Tables 1-2, pp. 108-109), but no taxonomic classification was provided.

8. Soil bulk density and organic matter content were reported in two samples but at only a single depth of 0-6 inches.

Study Deficiencies: Plant Effects

1. Due to the late season planting and the photosensitive nature of soybeans, the plants quickly transitioned to reproductive growth stages, and no growth occurred in control plants between the 14 DAT and 28 DAT when plant effects observations and measurements were collected. Therefore, the study author considered the plant height comparisons as unreliable, height was not analyzed by the study author, and the study stated "effects to non-tolerant soybean plants from spray drift and volatility from off-target movement could not be assessed" (pp. 67, 739; Appendix G, Table 2, p. 744; Figure 6, p. 752).

2. For both the volatility and spray drift portions of the study, the study author measured the height of a varying number of plants along each transect prior to test material application (volatility n=3-4; drift n=4-8; Appendix G, Table 1, p. 743). Following application, "At each distance along each transect, ten plants were selected non-systematically with no attempt to measure the same plant at the subsequent time points" (Appendix G, p. 727).

   The method presented by the study author indicates that no effort was made to determine uniform, homogenous, boundary-marked sampling sites at prescribed distances and sampling areas prior to treatment. OCSPP guidance recommends that the integrity of the replicate should be maintained throughout the duration of the study. In this study, plant height was determined for ten different plants at slightly different distances at each sampling interval. Although the study author reported that 'plants selected for plant height measurements were selected non-systemically as an unbiased representation for the population", the reviewer suggests that this sampling method is inadequate and introduces unnecessary variability into the study results that should have been more systematically controlled.

3. Because of the variability in plant height and stand condition, actual measurement distances differed from the target distances for some transects. These locations were selected by the study sponsor prior to application to avoid areas of nonstandard growth or inadequate soybean germination. All distances were adjusted based on GPS locations relative to the edge of the sprayed area.

4. Decreased number of replicates of transect distances resulted from the following reasons: DWA-D (ED) – the 50, 60 and 120m distances were removed due to prior injury and lack of space in the field. RWA volatility – 5 m distance was not sampled due to lack of plants (poor emergence) at that distance. UWA-D (SD) – the 40, 50 and 60m distances were not sampled due to poor emergence and weed pressure. RWB – the 120m distance was not sampled due to lack of plants at that distance (middle of farm road) (p. 62).

5. The study author did not provide historical germination rates for the soybean varieties planted.

6. The control plot was placed upwind of the treatment field. The specific distance upwind from the edge of the field was not reported.

7. Pesticides applications to the treatment field and test plots in 2019 were not reported.

8. The physico-chemical properties of the test material were not reported.

9. The Beck's 186899 variety of soybean that was planted in the test plots for both the volatility and spray drift study, is a non-Dicamba tolerant soybean. This variety was also selected because of its glyphosate-tolerance. It is uncertain if this genetically modified variety may have impacted dicamba effects compared to a non-genetically modified variety.

IV. **References**

Johnson, B., Barry, T., and Wofford P. 1999. Workbook for Gaussian Modeling Analysis of Air Concentrations Measurements. State of California, Environmental Protection Agency, Department of Pesticide Regulation. Sacramento, CA.

Maher, D. 2016. Storage Stability of Dicamba on Polyurethane Foam Air Sampling Traps. Monsanto Technical Report MSL0026782. St. Louis, Missouri.

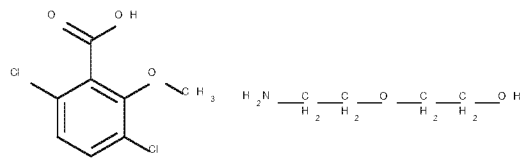
Majewski, M.S., Glotfely, D.E., Paw, K.T., and Seiber, J.N. 1990. A field comparison of several methods for measuring pesticide evaporation rates from Soil. Environmental Science and Technology, 24(10):1490-1497.

Wilson, J.D., and Shum. W.K.N. 1992. A re-examination of the integrated horizontal flux method for estimating volatilisation from circular plots. Agriculture Forest Meteor. Vol 57:281-295.

Yates, S.R., F.F. Ernst, J. Gan, F. Gao, and Yates, M.V. 1996. Methyl Bromide Emissions from a Covered Field: II. Volatilization," Journal of Environmental Quality, 25: 192-202.

Attachment 1: Chemical Names and Structures

Dicamba-diglycolamine and Its Environmental Transformation Products. [A]

Code Name/ Synonym	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR (day)	Final %AR (study length)
PARENT						
Dicamba-diglycolamine (Diglycolamine salt of dicamba)	IUPAC: 3,6-Dichloro-o-anisic acid-2-(2-aminoethoxy)ethanol CAS: 2-(2-Aminoethoxy)ethanol;3,6-dichloro-2-methoxy-benzoic acid CAS No.: 104040-79-1 Formula: $C_{12}H_{17}Cl_2NO_5$ MW: 326.17 g/mol SMILES: COc1c(Cl)ccc(Cl)c1C(=O)O.NCCOCCO		835.8100 Field volatility	51017503	NA	NA
MAJOR (>10%) TRANSFORMATION PRODUCTS						
No major transformation products were identified.						
MINOR (<10%) TRANSFORMATION PRODUCTS						
No minor transformation products were identified.						
REFERENCE COMPOUNDS NOT IDENTIFIED						
All compounds used as reference compounds were identified.						

[A] AR means "applied radioactivity". MW means "molecular weight". NA means "not applicable".

Attachment 2: Statistics Spreadsheets and Graphs

Supporting spreadsheet files accompany the review.

1. Air sampling periods and soil temperature and moisture graphs

   128931_51017503_DE
   R-FATE_835.8100_4-2(

2. Validation spreadsheet for the Indirect Method

   128931_51017503_DE
   R-FATE_835.8100_4-2(

3. Validation spreadsheet for the Integrated Horizontal Flux Method:

   128931_51017503_DE
   R-FATE_835.8100_4-2(

4. Validation spreadsheet for the Aerodynamic Method:

   128931_51017503_DE
   R-FATE_835.8100_4-2(

5. Air modeling files

   129831 51017503 air modeling.zip

6. Validation spreadsheet for spray drift calculations

   128931_51017503_DE
   R-FATE_840.1200_08-2

7. Terrestrial Plants: Vegetative Vigor. MRID 51017503, EPA Guideline 850.4150

   Folder: 128931 51017503 850.4150.

Attachment 3: Field Volatility Study Design and Plot Map

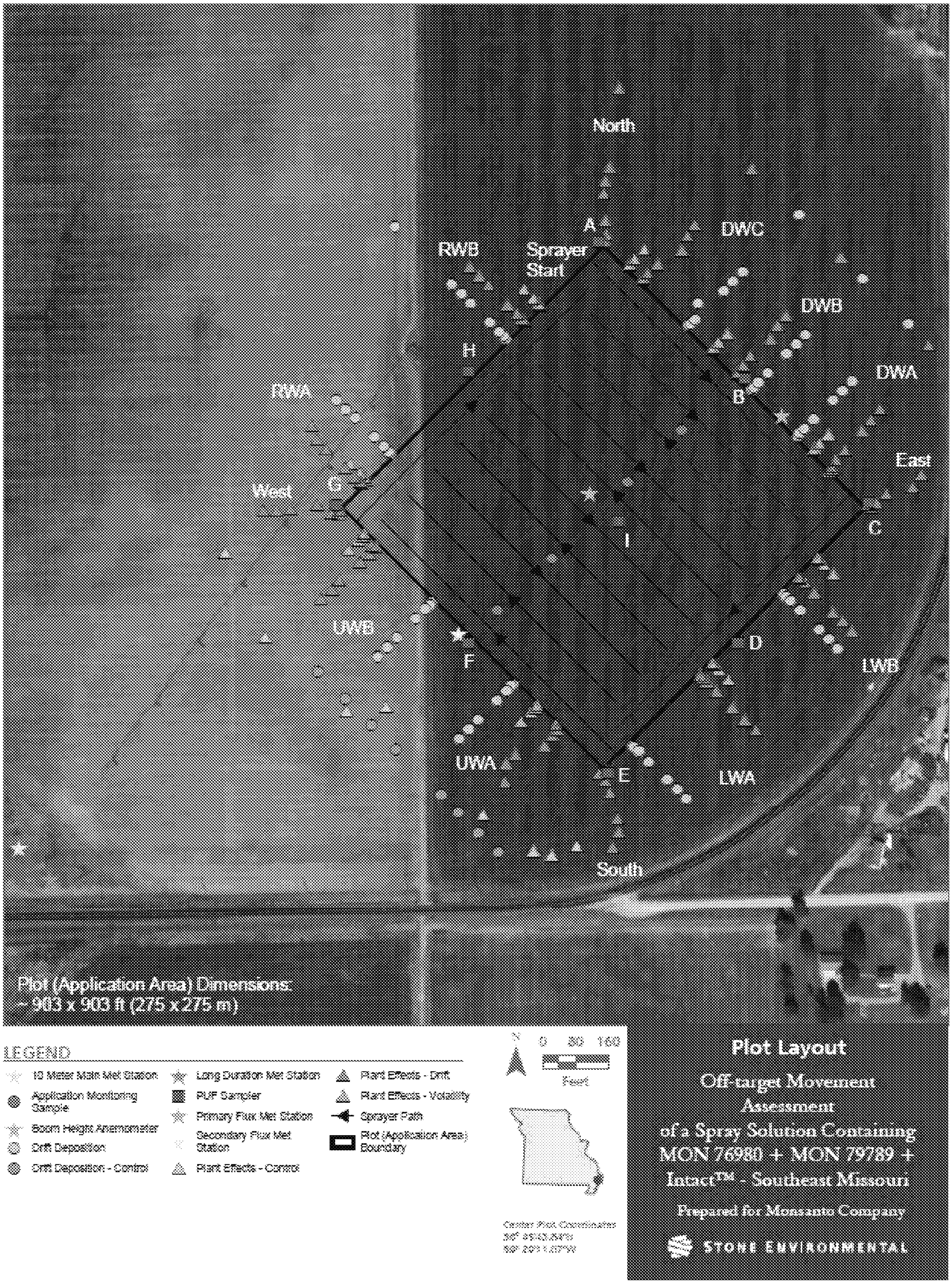


Figure obtained from Appendix B, Figure 1, p. 129 of the study report.